to the central structural element fixedly receives a pitch gauge 414. A user-interface system in the form of a personal digital assistant (PDA) system interface 318 (see Figure 16) is secured to the front structural member 34 via a mounting bracket 48. A remote control system 314 (see Figure 16) is also secured to one of the plied steel bracket 38 via a mounting bracket 52. Two fans 54 are provided in the body 12 and are secured to opposite iron angles 32. Of course, the number and location of the fans 54 may vary.

[0074] Four brackets 56 secured to the chassis 14, near its four corners, allow receiving the motors 84 of the steering assembly 20. A casing 58 is provided to receive a central ~~controller~~ control system 312 (see Figure 16). The casing 58 is mounted to the iron angles 32 via two precision ground ways 60. The ~~body 12~~ ~~includes a communication~~ central control system 312 is secured to the iron angles 32 via a bracket 64. Finally, two batteries 66 are secured to the iron angles 32 via brackets. It is to be noted that the sets of batteries 66 have been mounted to the chassis 14 so as to be positioned as low as possible, yielding a low center of gravity for the body 12. Of course, the number of batteries 66 may vary. The access to the sets of batteries 66 and to the central controller 312 is facilitated by the configuration of the iron angles 32, ground ways 60, and lower shell portion 82.

[0075] It is to be noted that the expressions "batteries" should be construed in a broad sense encompassing any portable power source, including battery packs, fuel cells, portable batteries, etc.

[0076] The steering assembly 20, central controller 312, pitch gauge 414, PDA system interface 318, and remote control system 314 will be described in more detail hereinbelow.

[0077] Turning now to Figures 4 and 5, external components of the body 12 will now be described.

[0078] The body 12 further includes four (4) rigid columns 68 secured to the chassis 14 near its four corners for securing external components of the body as will now be described.

(i.e. mounting plate)

[0079] A rectangular cover plate 70 is secured on top of the columns 68. The plate 70 allows receiving selected equipments (not shown) allowing the robot 10 to achieve specific tasks. Two handles 72 are also secured to the columns 68. The columns 68 also support two interface panels 74-76. A first interface panel 74 includes connections allowing connecting external modules on the CAN coordination buses 302-304 (see Figure 16), power supply (5V, 12V), video input ports (4), audio jacks (in-out), RS-232 jacks. A second interface panel 76 includes the external power supply connector, main power switch, reset button, and status leds. The first interface panel 74 includes connecting means, such as video connectors 432, USB ports 434, and other connectors to connect equipments (not shown) to be mounted on the plate 70.

X

[0080] As illustrated in Figure 5, a shell 16 that includes front and back portions 78, two side portions 80 and a bottom portion 82 protects the body 12. The shell portions 78-82 are secured to the chassis 14 and allow protecting the internal components. Since the shell 16 is divided in independent portions 78-82, each of these portions may act as a panel door allowing easy and fast access to a limited area of the internal parts of the body 12.

[0081] The chassis 14 and the other structural members of the body 12, including the different mounting brackets, are made of aluminum, of another rigid lightweight material or alternatively of any rigid material. Of course, in that later case, the resulting weight of the body 12 is increased, which may be detrimental to the autonomy of the platform 10.

[0082] Or course, the configuration and size of the chassis 14 and body 12 may vary depending, for example, on the application of the robotic

the optical encoder may be replaced by another pivot controlling means, such as rotary encoders, relative encoders, absolute encoder, synchro, resolver or LVDT converters, and potentiometers.

[0092] Alternatively to the motor 84 directly mounting the steering assembly 20 to the chassis 14, a pivoting shaft can be used providing an alternate motor to actuate the steering assembly 20. This alternate motor can be positioned within the steering assembly 20 or part of the legs 18 or in the body 12.

[0093] In some alternative embodiments of a robotic platform according to the present invention, only some of the locomotion members 18 may be provided with a motored steering assembly.

[0094] The drive system 24 of the drive assembly ~~22~~ will now be described in more detail with reference to Figures 7-11. The drive system 24 allows driving each leg 18 of the robotic platform 10 on a generally flat surface, on stairs or other broken grounds. The drive system 24 also allows controlling the track-tensioning assembly 28 in order to perform steps required in climbing a stair or to clear an obstacle. More specifically, the drive system 24 allows positioning and maintaining the track-tensioning assembly 28 to a selected angle with a precision of about one degree.

[0095] The drive system 24 includes two degrees of freedom: the drive speed, and the angle of the track-tensioning assembly 28.

[0096] As can be better seen in Figure 7, the drive assembly ~~24~~ includes a mounting assembly 110, the driving wheel's actuator 112, the track-tensioning assembly driving mechanism 114, and the driving wheel support structure 116.

[00105] The attach-bearing 168 is secured to the driving gear 154 on the periphery thereof. The attach-bearing acts as a protective disk mounted and is therefore mounted on the outer peripheral surface of the driving gear 154 so as to extend radially therefrom. In operation, when the robotic platform 10 moves on a generally flat ground surface and leans only on the driving wheel 162, the bearing point of the driving wheel 162 is on the attach-bearing, allowing minimizing friction between the track 166 and the ground. The attach-bearing 168 is covered by the coating 170 to minimize tearing of the bearing surfaces. The attach guidance 171 allows guiding the track 154, preventing the track 154 from contacting the track-tensioning assembly 28.

[00106] Referring now to Figure 13, the driven wheel 164 comprises a cylinder 172 closed at its two longitudinal ends by round clamping plates 174 including shoulders for limiting the axial displacement of the endless track 166. The driven wheel 164 is made rotatable about a shaft 176 fixedly mounted to plates 214 of the track tensioning assembly 28 therebetween by mounting the clamping plates 174 to the shaft 176 via ball bearings 178. Two rings 180 mounted to the shaft 176 are used to limit the axial displacement of the internal rings of the ball bearings 178.

[00107] Figure 14 illustrates the driving mechanism 114 of the track tensioning assembly. The driving mechanism 114 includes an inner toothed gear 182 secured to the track-tensioning assembly 28, a servo-disk motor 184 mounted to the plate 118 for driving the gear 182, and a speed-reduction gear set for transmitting the rotational movement of the motor 184 to the gear 182.

[00108] The speed-reduction gear set comprises two intermediate worm gears 186 and 188; a worm gear 190 and straight toothed gears 192-194. ~~An intermediate gear 195 directly mounted unto straight gear 192 allows coupling~~ The worm gear 188 to the straight gear 192.

intermediate is coupled

X

such as screws 209. Plates 214, together with plate 210, form a driven wheel-mounting bracket.

[00114] Contacts between the track tensioning assembly 28 and the drive system 24 are achieved via the inner tooth gear 182 (see Figure 14) that is radially fastened to a smooth part 218, which is part of the main support 198, using screws 219 or other fasteners. The main support 196 ~~198~~ also includes a smooth part 220. Circular friction reducing disks 222 and 224 are mounted to the smooth parts 218 and 220, respectively. The inner surfaces of the circular friction reducing disk 222-224 rest respectively on the outer surface 128-130 (see Figure 8).

[00115] Skid plates 226a and 226b are mounted to the track tensioning assembly 28 via brackets 228 and 230, respectively, to support the track 166.

[00116] Even though, the illustrative embodiment of the track-tensioning assembly 28 has been illustrated with screws and bolts as fasteners, other fastening means such as brackets or soldering may alternatively be used.

[00117] The general architecture 300 of the controllers of the robotic platform 10 will now be described with reference to Figure 16.

[00118] Contrarily to conventional robots, which include a single central processing unit to which all the sensors and actuators are connected, a modular robotic platform 10 according to the illustrative embodiment of the present invention includes dedicated sub-systems (or modules) communicating through a common data communication bus. Indeed, each sub-system includes its own processor.

instantaneous power at every computing cycle. At any time, the micro-controller 522 can receive a query from the central control system 312 ~~322~~ via the coordination bus 304 to provide the power level of any battery 66 or the instantaneous power, and to acknowledge if the switches are closed. Integrating instantaneous power over time by the micro-controller 522 gives the energy consumption.

[00147] The computer system 322 includes its own power controller 538 directly powered by the batteries 66 via the computer system switch 530.

[00148] The motors 84, 132, and 184 are powered directly by the batteries 66 via 24V power controllers 540.

[00149] The energizing system 306 further includes two connectors including four wires (5V, 12V, ground, reset) that are available to power additional electrical systems (not shown) part, for example, of the equipments that can be carried by the robotic platform 10.

[00150] Finally, the energizing system 306 comprises three (3) LEDs (Light Emitting Diode) 544-548 that are located on the display panel 76 (see Figure 4):

[00151] – LED "ON" 544: this diode serves to indicate that the robot 10 is in operation;

[00152] – LED "PC ON" 546: this diode serves to indicate that the computer 322 is energized; and

[00153] – LED "LOW BATTERY" 548: this diode serves to indicate that the battery level is low.

[00154] Of course, the configuration of the energizing system ~~308~~ 306 may vary without departing from the spirit and nature of the present invention.

[00155] Returning to Figure 16, the modular robotic platform 10 further comprises four locomotion controllers 308, for controlling each of the four legs 18 independently. More specifically, the locomotion controller 308 is configured to control the three following motors of the locomotion members 18: the drive motor 132, the steering motor 84 and the motor 184 of the track-tensioning assembly 28.

[00156] More specifically, the locomotion controller 308 is in the form of an electronic board including a micro-controller (both not shown) connected to two other electronic boards dedicated to manage the power supply of the motors 84, 132, and 184, to read the steering assembly (direction) position encoder 94 (see Figure 6), and the limit switches 309 (see Figure 7) of each leg 18. Each locomotion controller 308 allows controlling the motors 84, 132, and 184 to provide a selected speed, acceleration, and position of the corresponding leg 18. The data related to the speed, acceleration and position of each leg 18 is communicated to the other locomotion controller 308 via the synchronisation bus 302.

[00157] More specifically, with reference now to Figure 20, each locomotion controller 308 comprises three power systems: a first one for the drive system 24, a second one for the steering assembly 20 and a third one for the track-tensioning assembly 28. Each of these three power systems allows controlling and powering specific motors of a leg 18. According to the illustrative embodiment of Figure 20, the maximum current for each motor of 100 A.

[00158] The position sensors 324, 328, and 332 include three types of sensors: position encoders, optical sensors, and the limit switches. Optical

sensors mounted to the steering assembly and to the tensioning assemblies are used to assess the initial position of the systems, acting similarly to limit switches. More specifically, the initial position is determined when a strip (not shown) cut the infrared beam of the optical sensor.

[00159] The position encoder of each motors 84, 132, and 184 are connected to an external counter (not shown). This counter increases or decreases depending on the direction of rotation of the motor. The external counter is connected to the micro-controller 336, allowing the locomotion controller 308 to query the counter. Other sensors may also be included to the platform 10.

[00160] Power sources 326, 330, and 334 are in the form of motor power circuits providing 100 A to each motors 84, 132, and 184. The motor power circuits are connected to the locomotion controller 308. This allows the locomotion controller 308 to measure the current in each motor 84, 132, and 184 and to detect whenever a motor is stalled, unplugged, etc.

[00161] The locomotion controller 308 is connected to the two communication buses 302-304 via respective bus interfaces 338-340. As mentioned hereinabove, the coordination bus 304 (see Figure 16) manages communication among all modules of the platform 10. Indeed, the central control system 312 can send commands pertaining to the angular position, the speed, and the acceleration, to the locomotion controllers 308. The synchronisation bus ~~338~~ 302 manages the synchronisation of the legs 18. The locomotion controller uses the synchronisation bus 302 for the simultaneous automatic control of the motors 84, 132, and 184 of the four legs 18.

[00162] Alternatively, independent controller may be provided for each motor 84, 132, or 184.

[00180] The central control system 312 further comprises a LED identified "Alive" to signal a user that the platform 10 is efficiently operational. This LED is mounted to the panel 76 (see Figure 4).

[00181] Supplemental LEDs 370 may also be provided to indicate the efficient operation of specific components of the platform 10.

[00182] Of course, other information display means may alternatively be provided instead of the LEDs 368-370.

[00183] Emergency buttons 372 connected to the micro-controller 364 are located at each corner of the body 12 and more specifically on the shell 16. The micro-controller 364 is configured to detect if any buttons 372 are depressed and then to initiate predetermined safety actions such as cutting the power to the motors. Emergency CAN messages can also be sent, requiring actions from different systems according to the situation.

[00184] Alternatively, the functions of the central control system 312 may be embedded in some of the other modules such as in the onboard computer system 322 for example.

[00185] Turning now to Figure 23, the remote-control system ~~316~~ 314 comprises two (2) sub-systems: a remote control 374 and a receiver 376 mounted to the body 12 of the robotic platform 10. The remote control 374 comprises a power source in the form of rechargeable batteries 378. Even though 4 AA batteries providing 4.8V are used in the illustrated embodiment, the remote-control 374 can be configured so as to be powered by other types of batteries. Of course, single-use batteries can also be used. X

[00186] A switch 380 allows to selectively energizing the remote control 374. A voltage doubler 382 allows to raise the batteries output to 9,6

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Inventor(s): Michaud et al.
Serial No. 10/724,519
Atty Docket No. BKP-007
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Drawings Marked-Up Showing Amendments
Page 1 of 9

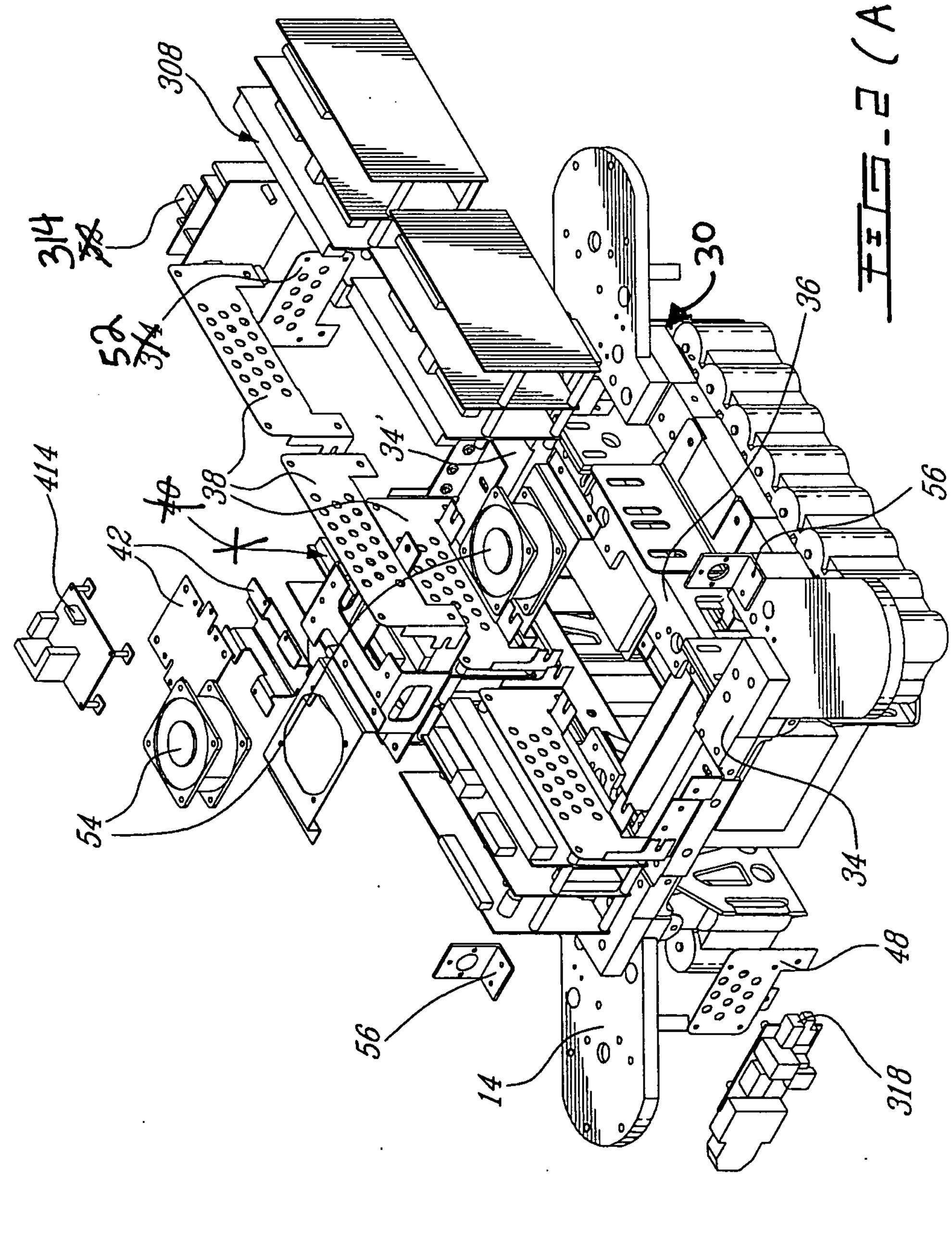

FIG. 2 (AMENDED)

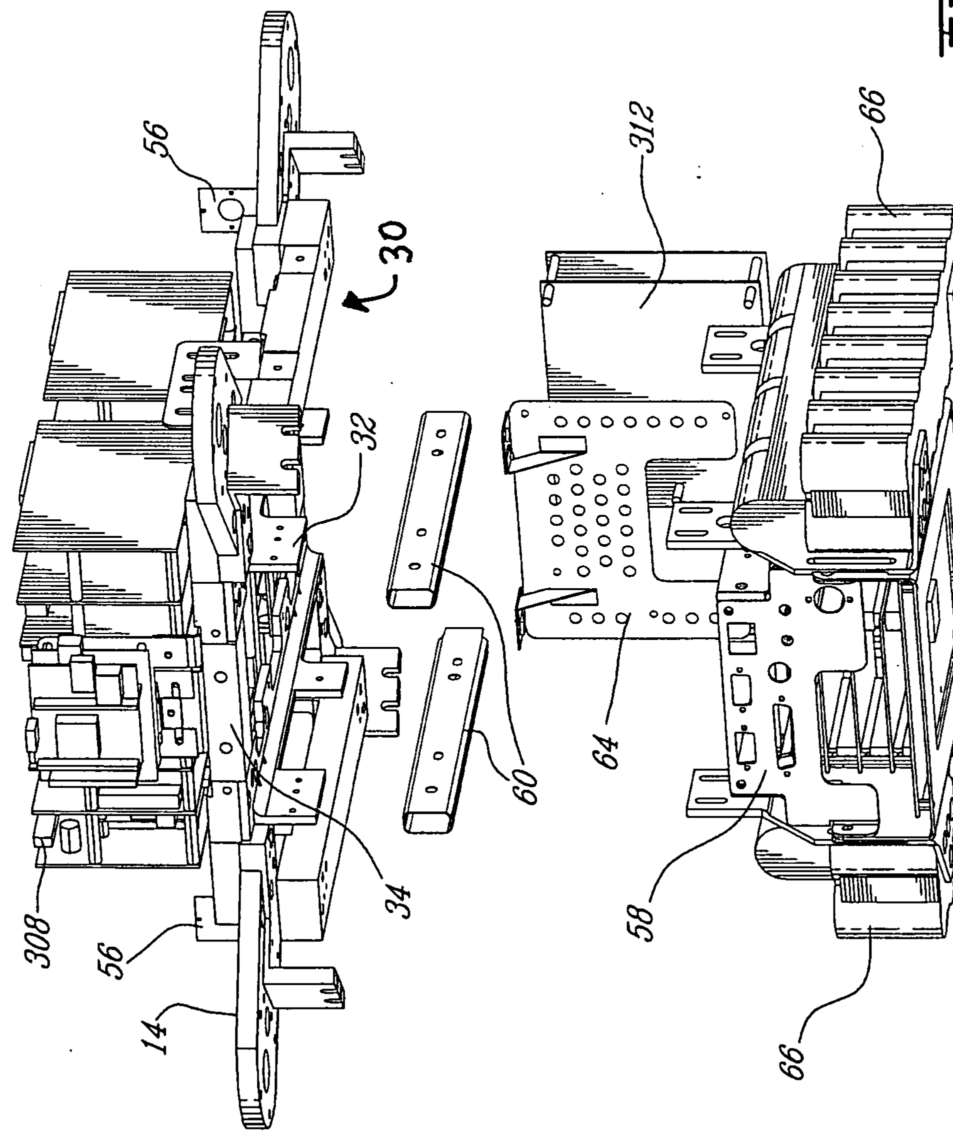

FIG. 3 (AMENDED)

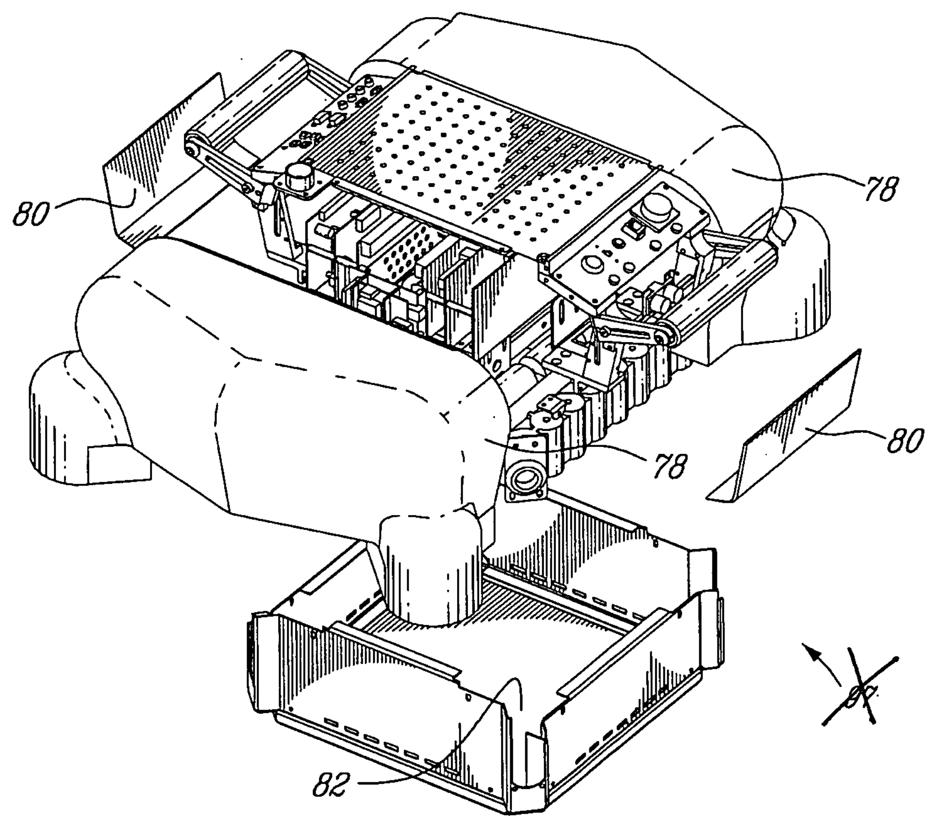

FIG. 5 (AMENDED)

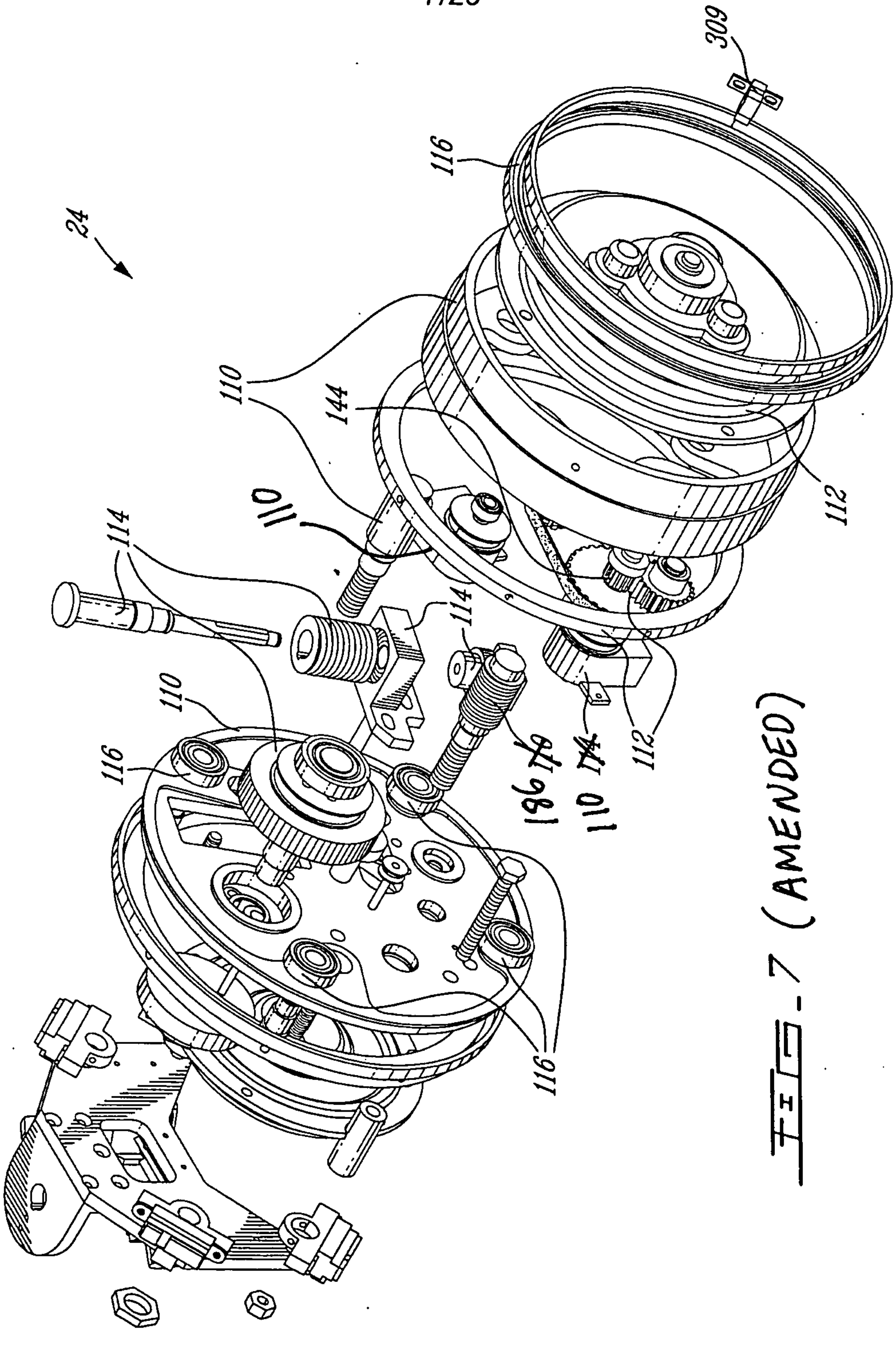

FIG_7 (AMENDED)

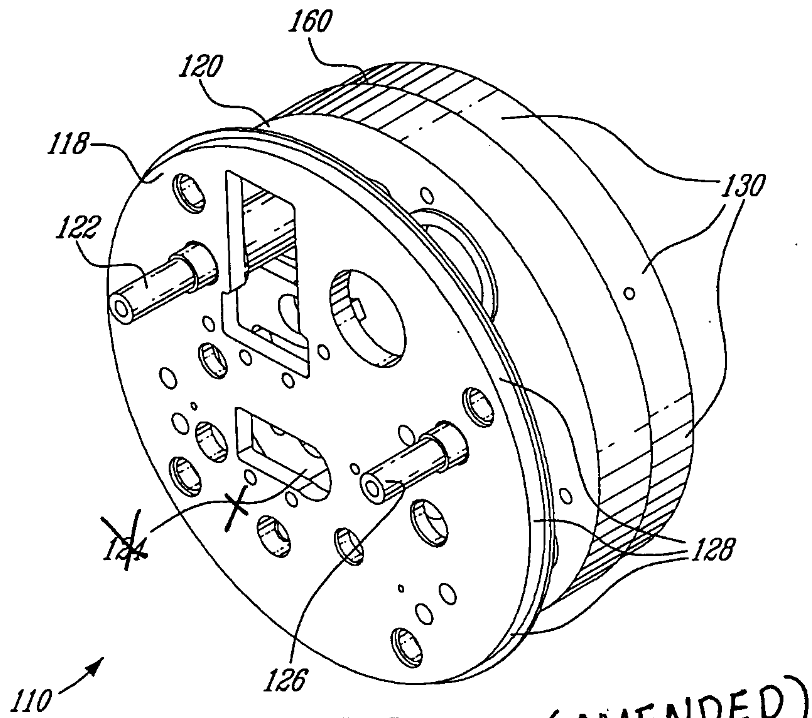

FIG. 8 (AMENDED)

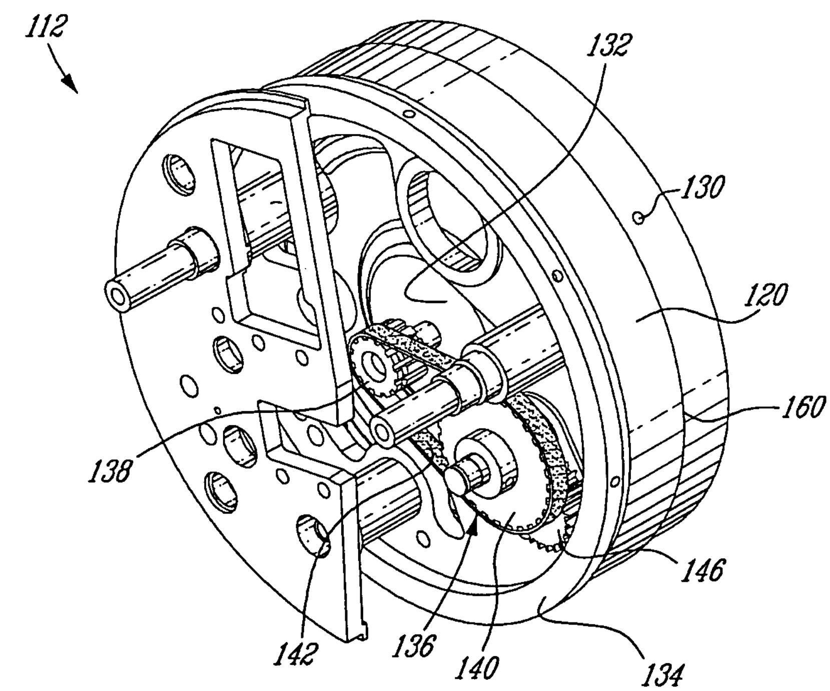

FIG. 9

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Inventor(s): Michaud et al.
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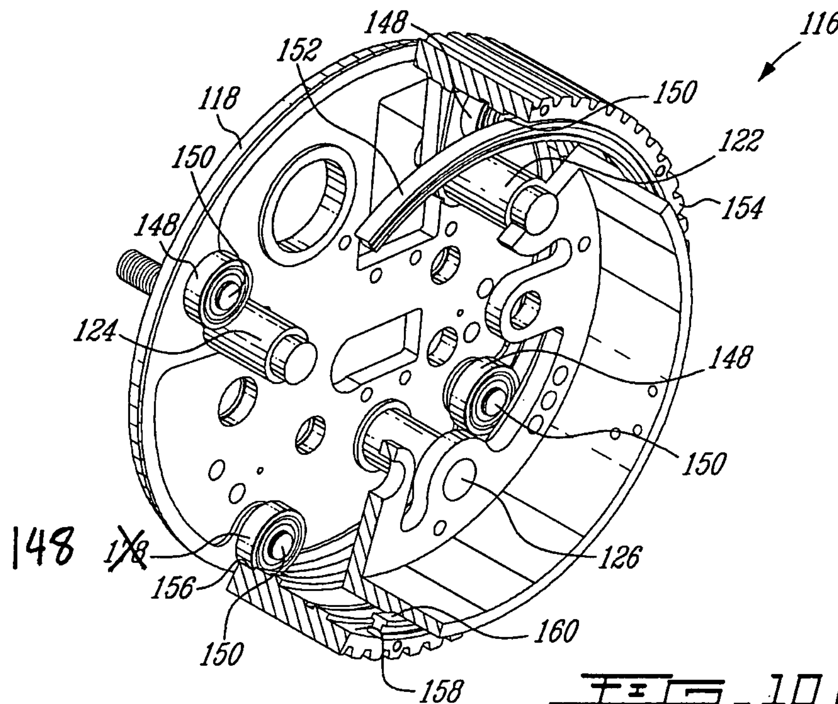

FIG. 10 (AMENDED)

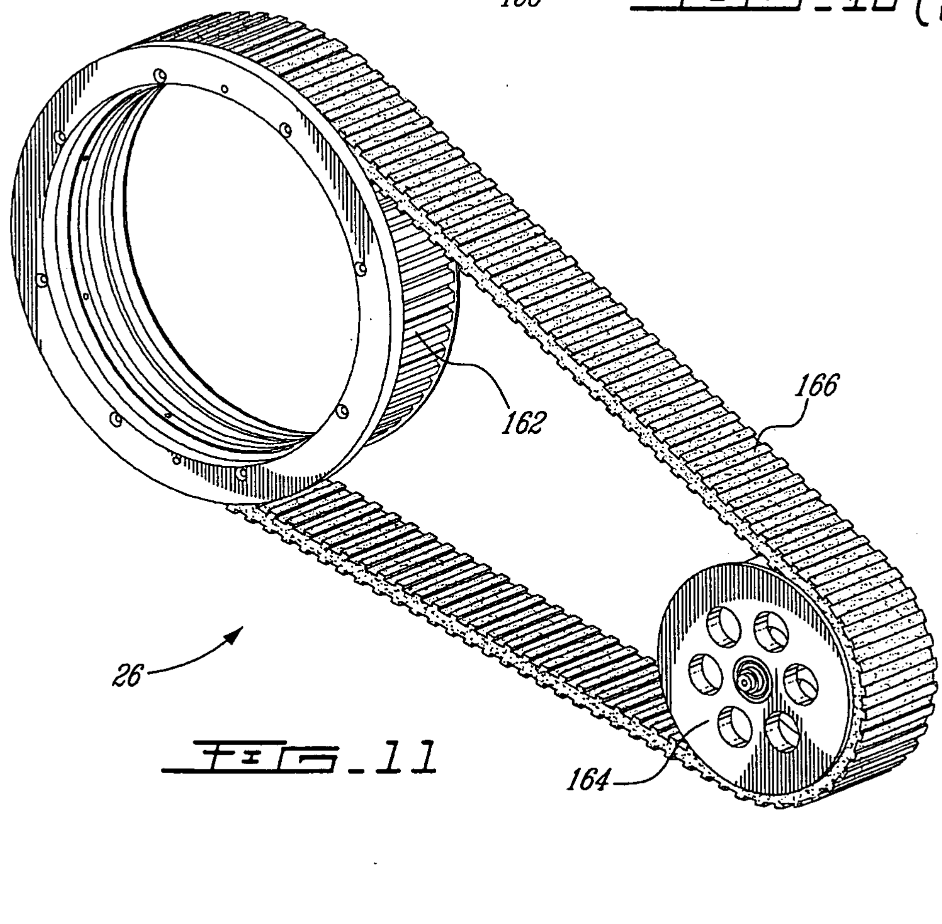

FIG. 11

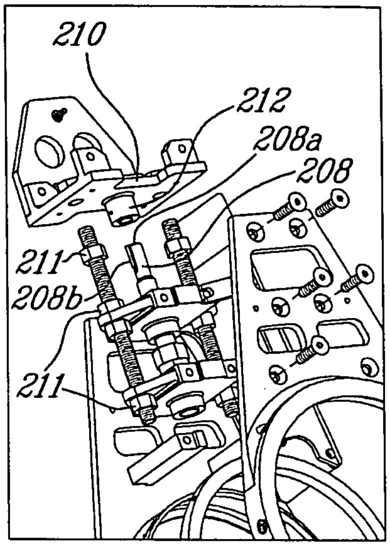

FIG. 15A

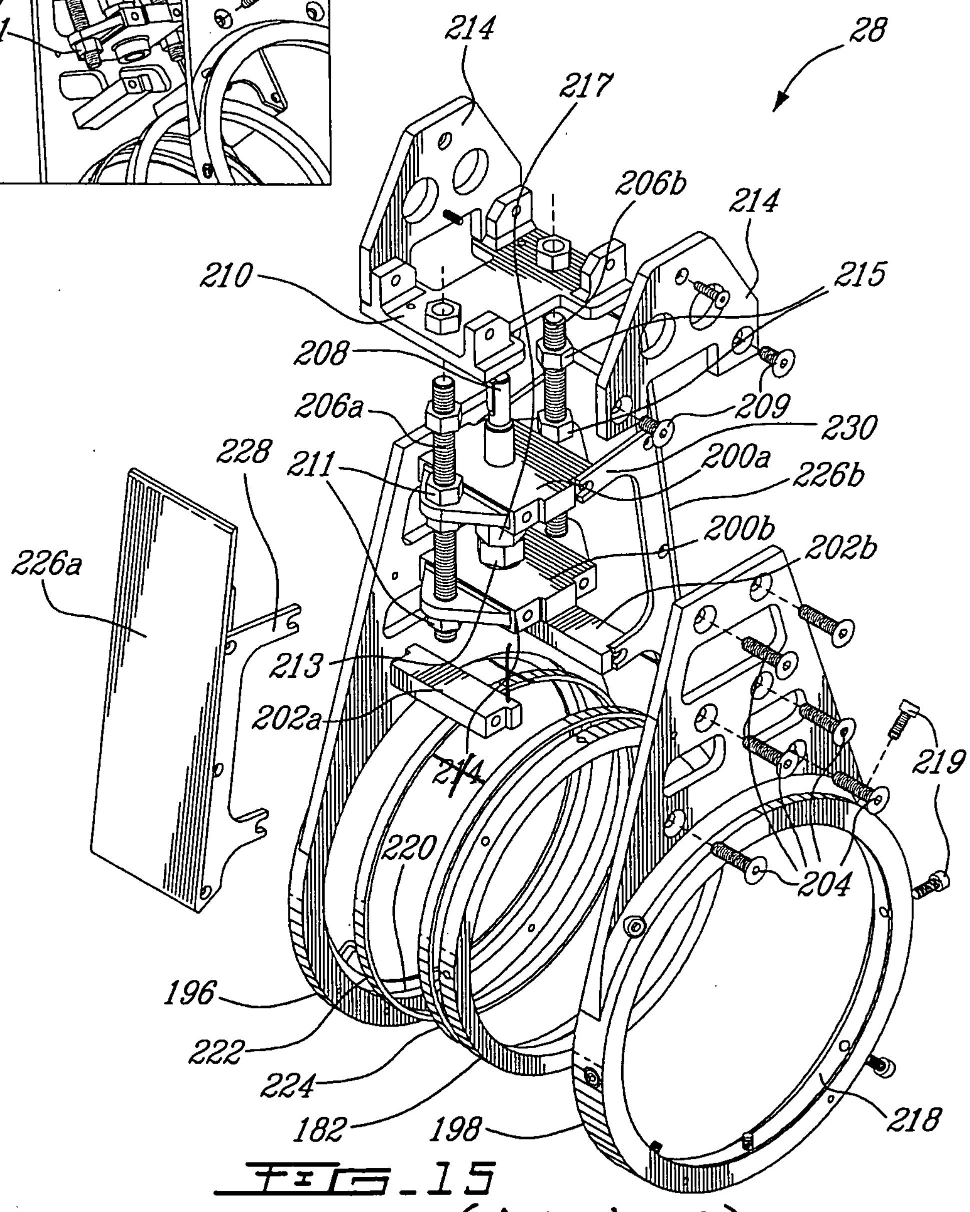

FIG. 15
(AMENDED)

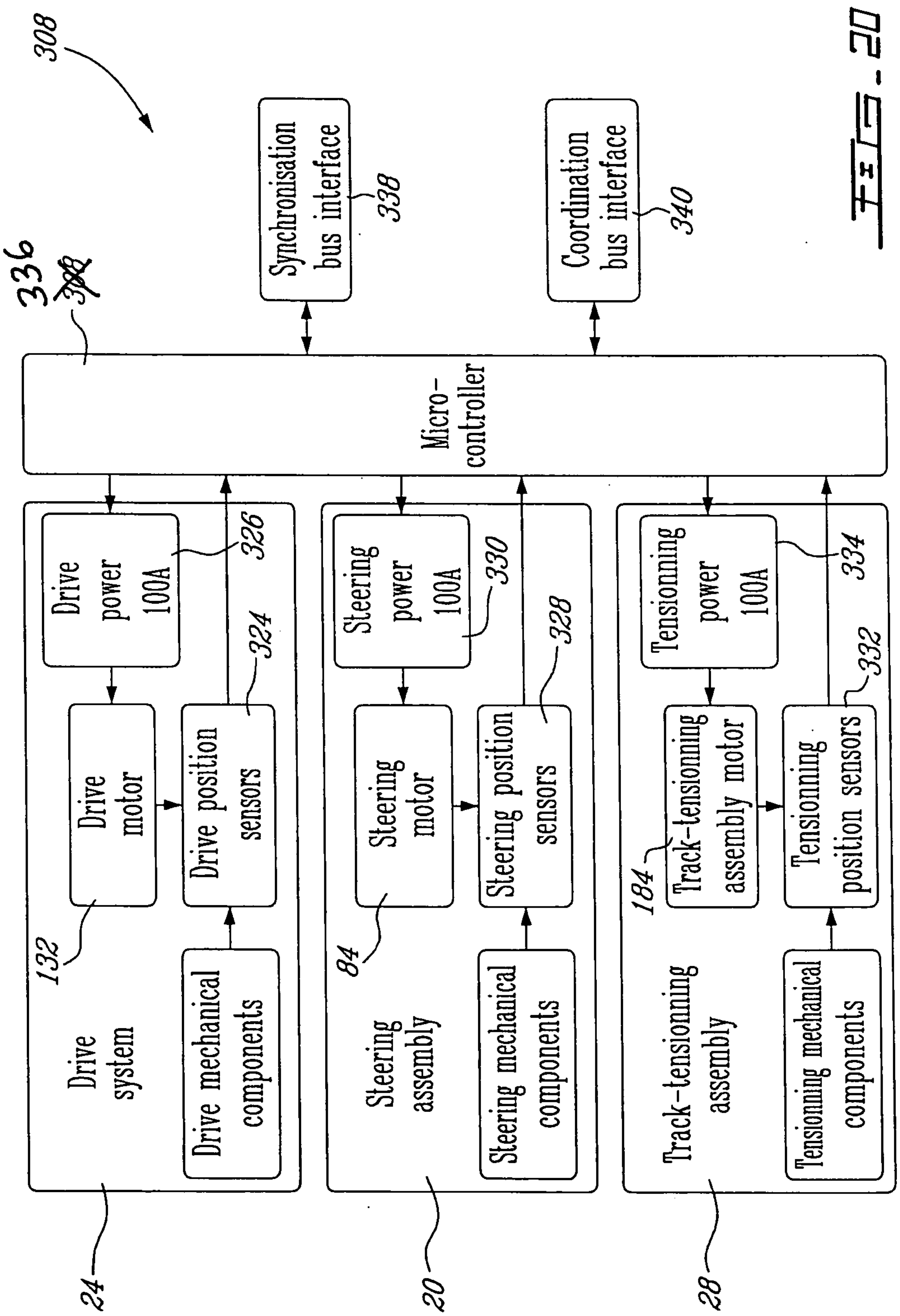

FIG. 20 (AMENDED)

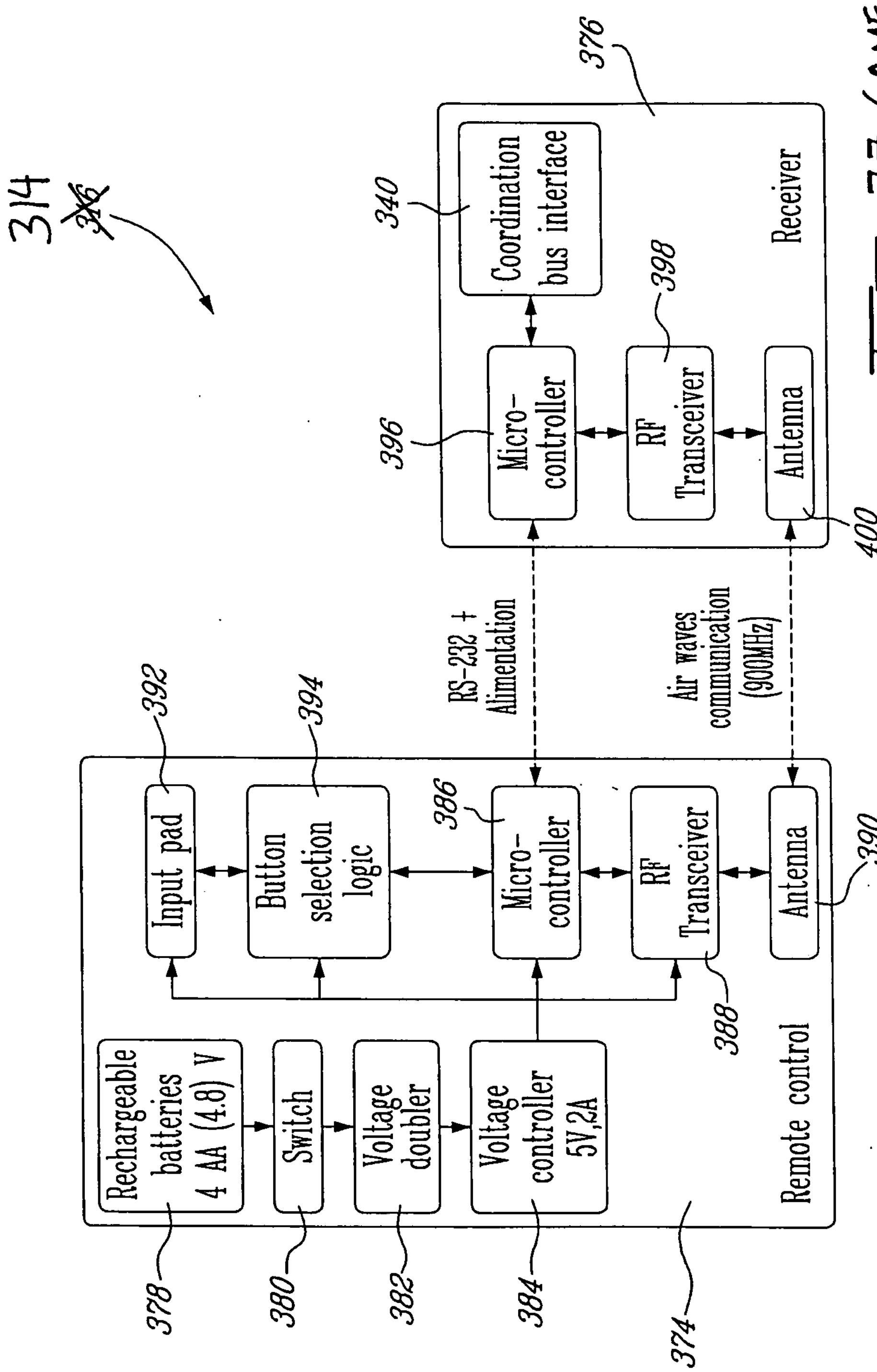

FIG-23 (AMENDED)